# Rethinking Resilience – The Underground Option

**ARPA-E Undergrounding Workshop** 

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### Vision

To be a world leader in advancing science and technology solutions for a clean energy future

### Mission

Advancing safe, reliable, affordable, and clean energy for society through global collaboration, science and technology innovation, and applied research.

Together...Shaping the Future of Energy®



### **EPRI's Technology Milestones Over the Decades**





- Nondestructive Evaluation Center
- Coal Cleaning Test Facility
- Transmission Line Mechanical Research Facility
- High-reliability gas turbine combustion system prototype
- Initiate Advanced Light Water Reactor program
- Developed HydroTech 2000 heat pump

ADDRESSING INDUSTRY NEEDS



- Information exchange a greement signed between EPRI and the European Commission
- Intelligrid vision initiated
- "CoalFleet for Tomorrow"
- Plug-In Hybrid Electric Vehicles (PHEV)
- PRISM/MERGE analysis
- Integrated-gasification combinedcycle (IGCC) technology with CCS

NAVIGATING A
NEW CENTURY



- Climate READi
- Low-Carbon Resources Initiative
- Artificial Intelligence
- Advanced nuclear and fuels
- Wind and solar data analytics
- State electrification projects
- Electromagnetic Pulse (EMP)
- EPRI U training

DECARBONIZING
THE FUTURE

### SHAPING THE ORGANIZATION

- Electric Power Research Institute formed
- Six Cities epidemiological study of air pollution
- Formation of Steam Generation Owners Group
- Electric vehicle fleet van demonstration
- Organizational framework for the Institute of Nuclear Power Operations (INPO)



### EXPLORING NEW TECHNOLOGIES

- Utility Communications Architecture
- Model Evaluation Consortium for Climate Assessment
- First power electronicscontrolled, variable-speed wind turbine
- EPRI NOx Control Guidelines used in boiler NOx control retrofits
- Developed ultrasonic method for removing deposits from nuclear fuel



### DEVELOPING INTEGRATED ENERGY NETWORK

- Modular nuclear plants
- Smart Grid demonstrations
- Carbon Capture and Sequestration
- Cycling impacts on baseload plants
- Cyber security initiative launched
- Worker safety ergonomic handbooks
- · Long-term storage of nuclear fuel
- U.S. National Electrification
   Assessment US-REGEN models









### **Nonprofit**

Chartered to serve the public benefit, with guidance from an independent advisory council.



### **Thought Leadership**

Systematically and imaginatively looking ahead to identify issues, technology gaps, and broader needs that can be addressed by the electricity sector.



### Independent

Objective, scientific research leading to progress in reliability, efficiency, affordability, health, safety, and the environment.



### Scientific and Industry Expertise

Provide expertise in technical disciplines that bring answers and solutions to electricity generation, transmission, distribution, and end use.



### Collaborative Value

Bring together our members and diverse scientific and technical sectors to shape and drive research and development in the electricity sector.

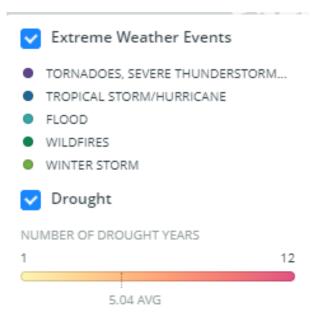


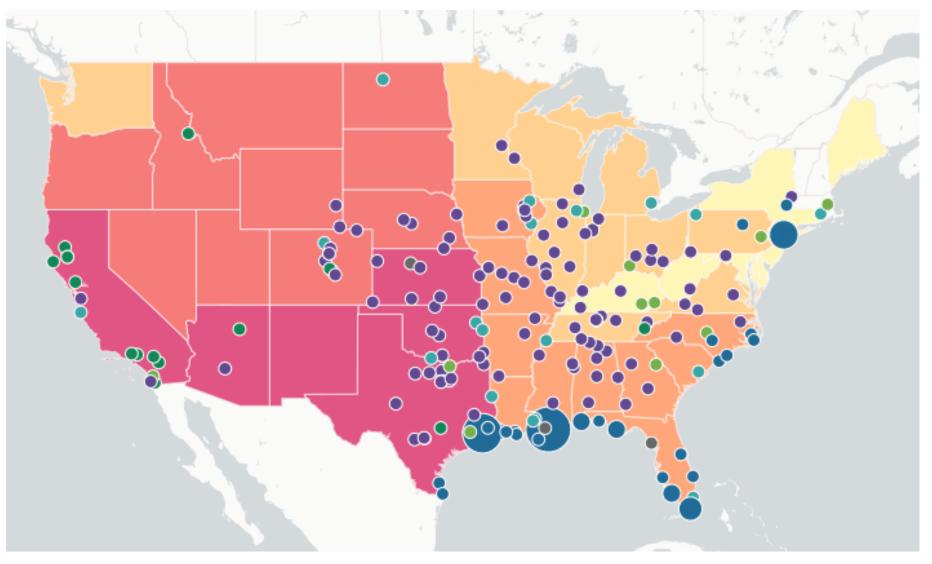
# All overhead systems remain exposed to major weather stressors





### Extreme Weather on the Rise





https://www.c2es.org/content/extreme-weather-and-climate-change/



### Increased need for resilience

Changing customer expectations

Increase in electrification

Dependence on grid for enabling DER

Post covid – every home is an office



## **Resiliency Options**

## Design Decisions

Enhanced vegetation management

Improved storm response practices

Proactive undergrounding



What can we learn from resilience of Overhead?



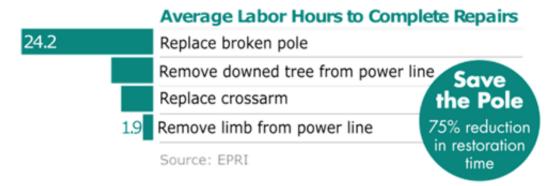
Small design changes can have large impact



### Lab testing can identify practical changes that could have large impact







#### Goal

• Reduce restoration time through improved distribution designs

### Approach

 Specialized full-scale test site at EPRI's Lenox Lab simulates tree strikes

### **Progress**

More than 75 structures tested for 12 utilities

### **Impact**

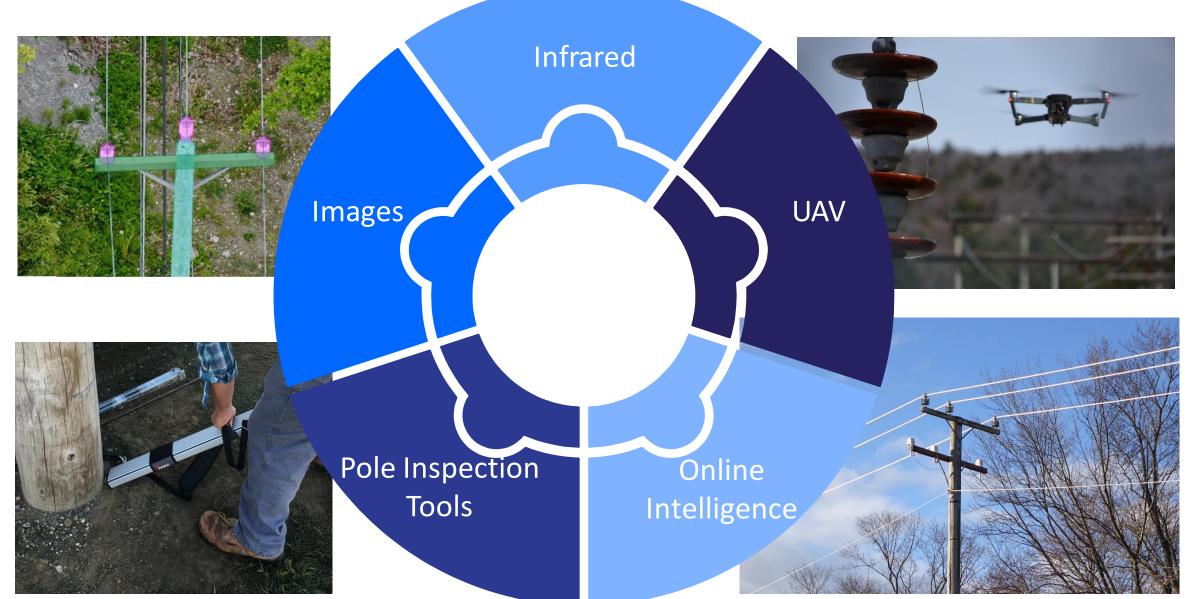
• Single utility improved 13 standards and created 8 new standards, projecting >10% improvement in SAIDI



The system WILL be stressed



## Robust inspection programs are key to resilience

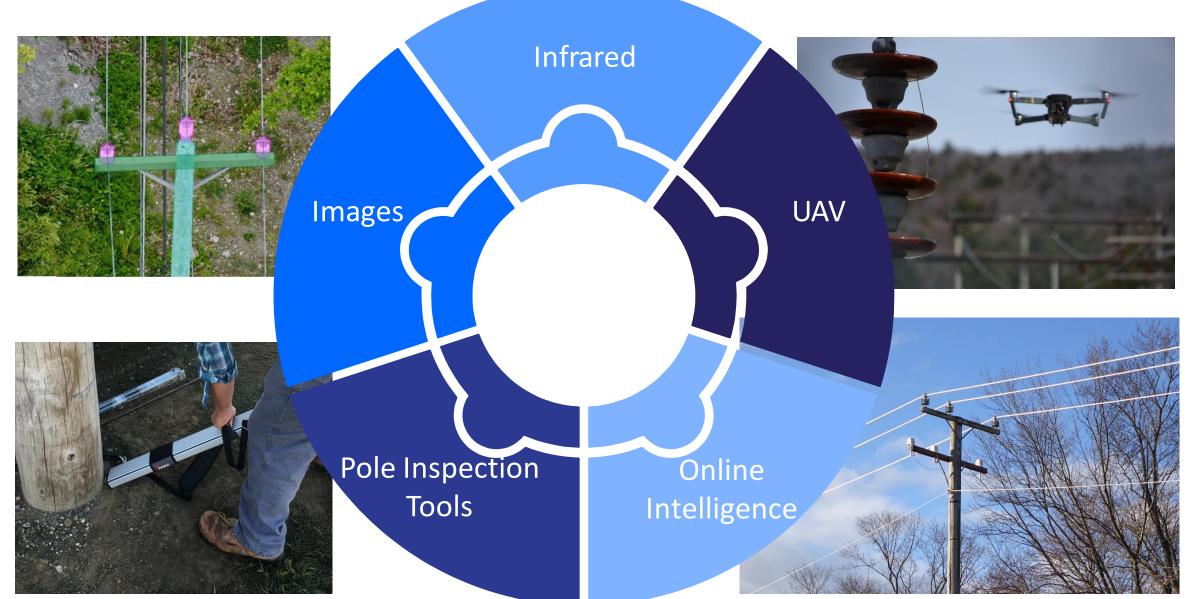




Asset lifespans can be LONG



## Ability to incorporate new technologies is critical

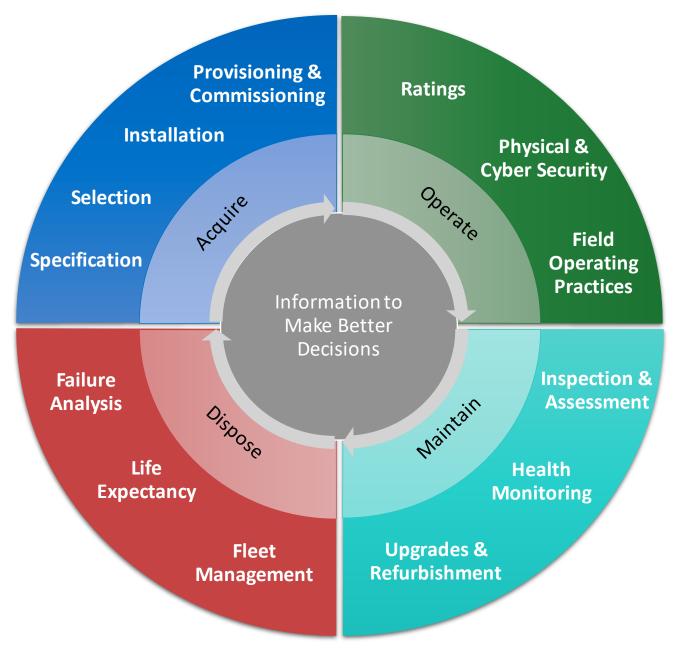




## Consider the life-cycle

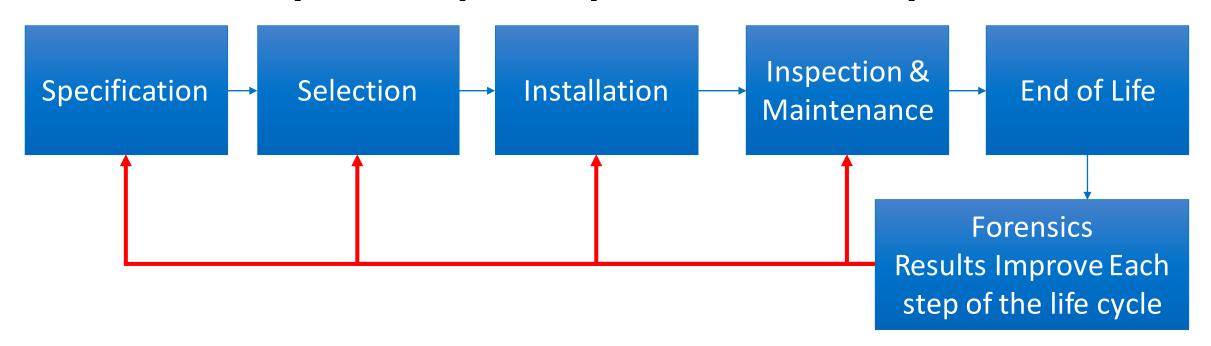


## **Asset Lifecycles**





### Forensic analyses helpto improve the life-cycle





## Robust, realistic laboratory testing is critical





## Robust, realistic laboratory testing is critical

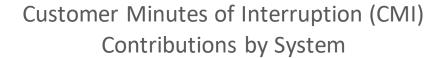




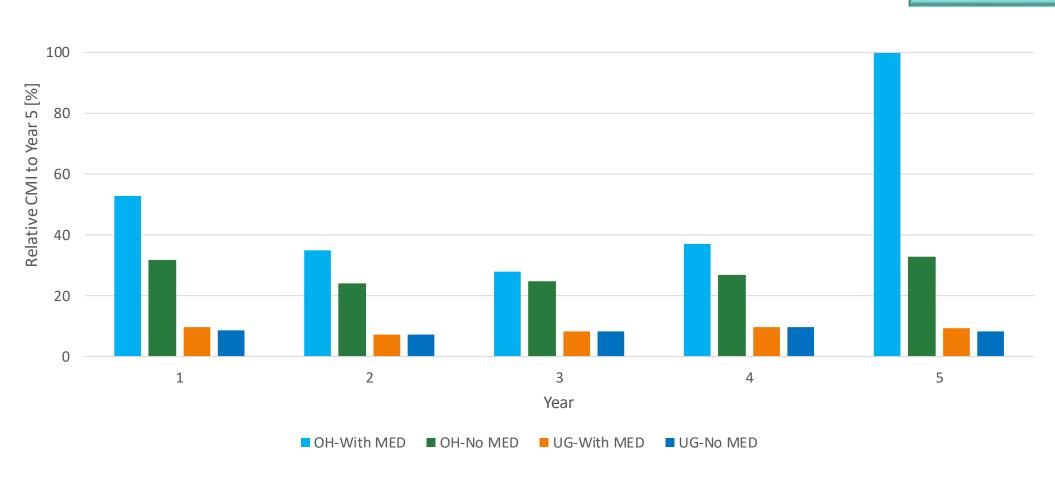




### **Underground vs Overhead**



Overhead systems vulnerable to major event days (MED) while underground systems are largely unaffected

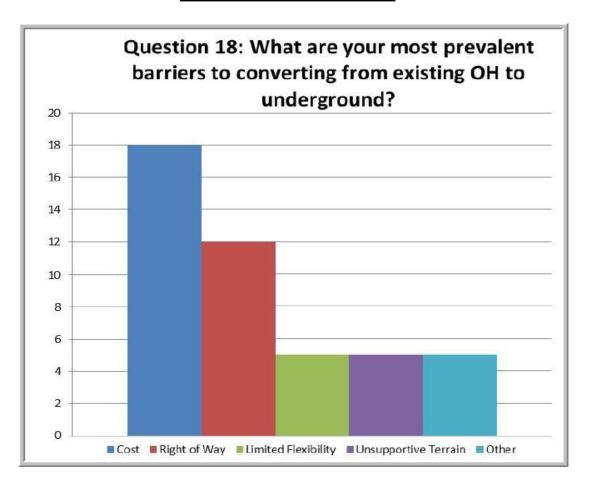




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## **Undergrounding Challenges**

### **2015 Survey**



### **2022 U-DIG Survey**

#### CUSTOMERS

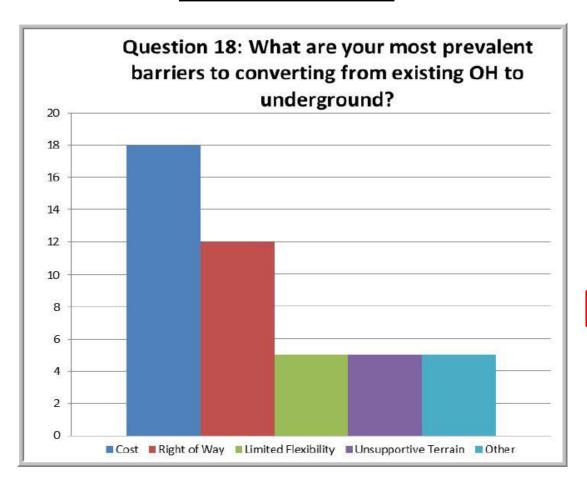
Other UG utilities such as sewer, water, gas. Cost and Maintenance Meter relocation/Secondary conflict with other utilities infrastructures. Costs, space in the streets services, joint utilities, and road crossings Access cost and technology cost mand customer buy in moneyspace & cost proof for cost Locating Equipment st cost, real estate. construction resources Cost and permitting Permission base rate cost per mile Complexity cost justification regulatory Right of way acquisition Obtaining permits \$\$ Cost and locating switchgear coordination existing infrastructure obtaining community approvals/easement Cost and space Cost and labor Technical and construction resources Customer concerns with equipment placement Cost and secondary service interconnect.

Cost continues to be leading challenge in proactive undergrounding

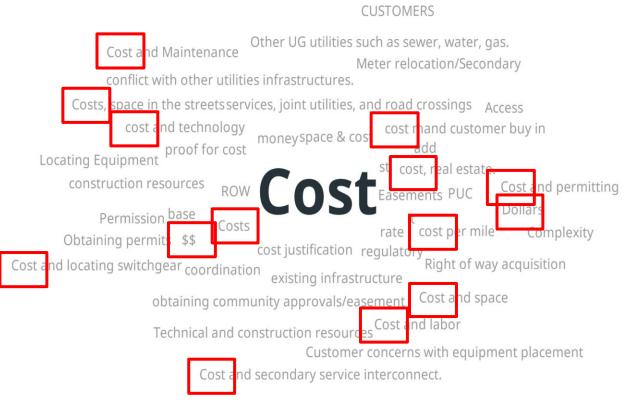


## **Undergrounding Challenges**

### **2015 Survey**



### 2022 U-DIG Survey



Cost continues to be leading challenge in proactive undergrounding



## **Proactive Undergrounding**

	Average	Range
Urban areas: 150+ customers/mile	\$1.9M	\$180k - 8M
Suburban: 51 to 149 customers/mile	\$1.1M	\$165k - 2.5M
Rural: <51 customers/mile	\$900k	\$145k - 2M

Based on 2013 survey https://www.epri.com/research/products/3002006782



EPRI is currently hosting a utility interest group focused on

undergrounding

Sharing of cost reduction strategies

Discussions of new technologies & installation practices

- Better understanding of optimal undergrounding project design
- Provide a centralized repository of information for members
- Identification and prioritization of R&D needs

https://distribution.epri.com/u-dig/







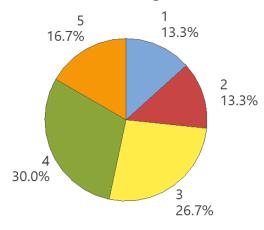
### **U-DIG Participation**

347 Utility Participants to date from 50+ **Utilities** 

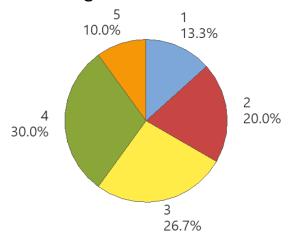


## **Utility Interests for Undergrounding**

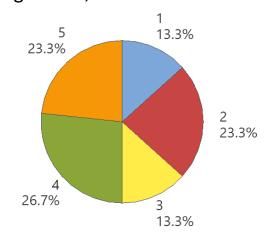
Identify / develop repair technologies



Improve sensing and awareness of existing UG infrastructure

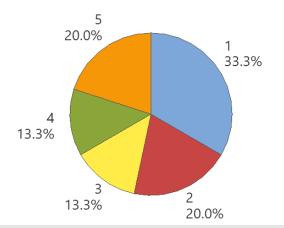


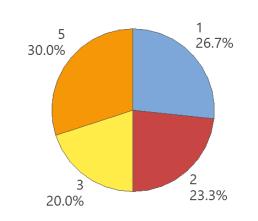
Incorporate health diagnostics, prognostics, and fault location



Reduce civil work required

Reduce errors in UG installation





Ranking

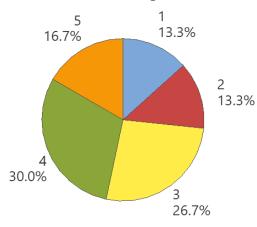
1 = Highest importance

5 = Lowest importance

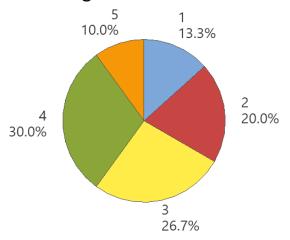


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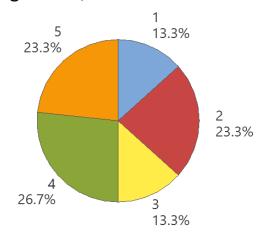
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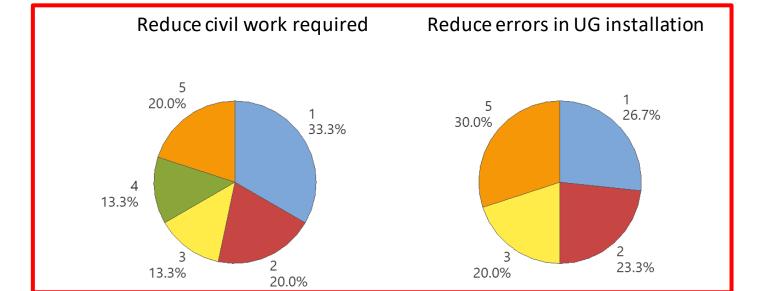


## Improve sensing and awareness of existing UG infrastructure



## Incorporate health diagnostics, prognostics, and fault location





#### Ranking

1 = Highest importance

5 = Lowest importance



### Looking ahead

- The future distribution system will likely require increased rates of undergrounding
- In the short term technology is needed to enable undergrounding to be:
  - Fast
  - Cost-effective
  - Safe
- In the long-term UG systems should leverage R&D to remain healthy with continued performance improvements



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